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ABSTRACT

The National Council of Teachers of Mathematics (NCTM) recently published two documents, "Curriculum and Evaluation Standards for School Mathematics" (1989) and "Professional Standards for Teaching Mathematics" (1991), (the "Standards Documents"), that recommend departure from conventional forms of instruction and assessment. This paper presents four case studies of teachers who were known to have begun implementation of the instructional practices suggested by the NCTM "Standards Documents" in order to profile their instructional and assessment practices. The teachers were nominated by local-area school district mathematics coordinators and the state mathematics supervisor. Interviews, observations, and collections of teacher-used materials provided information about the two types of practices. Analysis of the data produced several findings. All the teachers recalled some event in their professional past that was instrumental in changing their instructional and assessment practices. Instructional practices among the four teachers was diverse. Three teachers utilized a lecture/expository approach as the primary mode of instruction, while at the same time applying portions of the "Standards Documents." Each teacher had an instructional focus. One frequently used manipulatives, one used a curriculum that emphasized computer-assisted student explorations, one assigned projects by which students gained understanding, and one used a constructivist-learning approach. Teachers assessment practices were consistent with their teaching practices, and were used for grading purposes in three out of four cases. Each teacher articulated a desire to change their assessment practices, but felt constrained by time, lack of collegial contact, and curricular demands. (MDH)

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# A DESCRIPTION OF THE ASSESSMENT PRACTICES OF TEACHERS WHO HAVE BEGUN TO IMPLEMENT THE INSTRUCTIONAL PRACTICES SUGGESTED IN THE NCTM STANDARDS DOCUMENTS

by

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ABSTRACT

The National Council of Teachers of Mathematics (NCTM) recently released two documents that propose to dramatically change the content, instruction, and assessment of school mathematics and the preparation of teachers of mathematics. The documents are the Curriculum and Evaluation Standards for School Mathematics ( NCTM, 1989) and the Professional Standards for Teaching Mathematics (NCTM, 1991). The documents were developed through an unprecedented level of collaboration between mathematicians, mathematics teachers, mathematics teacher educators, and representatives from business, industry, and other academic disciplines. The recommendations made in the Standards Documents have resulted from the recognition that our understanding of how students learn mathematics has departed from current practices in mathematics education. Conventional forms of instruction and assessment do not address current emphases on understanding and problem-solving.

Four teachers who were known to have begun implementation of the instructional practices suggested by the NCTM Standards Documents were studied so their instructional practices and assessment practices could be profiled. Interviews, observations, and collections of teacher–used materials provided information concerning the two types of practices.

Teachers who participated in this study were nominated by local-area school district mathematics coordinators and the state mathematics supervisor. The coordinators listed and rank-ordered the names of ten teachers according to the coordinators knowledge of the teachers' level of implementation of the Standards Documents in their teaching practices. The coordinators used sections selected by the investigator from the Standards Documents to guide their nominations and rank-ordering. The list was used to contact nominees to see if they were interested in being a part of the study. Only five calls were needed to secure the four participants.

Teachers were profiled according to relevant sections of the Curriculum and Evaluation Standards and the Professional Standards. Of interest in the findings from the teachers was their level of implementation of the Standards Documents, the alignment of their instructional and

assessment practices, what problems the teachers encountered in their attempts to implement the Standards Documents, and how the teachers dealt with those problems.

All the teachers recalled some event in their professional past which was instrumental to their adopting a philosophy of instruction that is consistent with the Standards Documents. In each case, the teacher's decision to move away from conventional instruction came before the publication of the Standards Documents.

The instructional practices of the participating teachers were diverse with respect to implementation of the Standards Documents. Three of the teachers used a lecture/expository approach as the primary mode of instructional, at the same time applying portions of the Standards Documents. One teacher frequently used manipulatives in her instruction, one teacher used a curriculum which integrated computers while students explored concepts, and the other teacher assigned projects by which students gained understanding. The fourth teacher engaged her students in activities which facilitated the construction of their own representations for the concepts being studied and used the lecture/expository approach only for summarizing student investigations.

The teachers' assessment practices were consistent with their teaching practices. The teachers questioned their students during class discussions, collected and checked assignments, administered quizzes, and gave tests which could be retaken if certain responsibilities were met. The fourth teacher above was able to make the students an integral part of the assessment process while the other teachers used assessment mainly for grading purposes. Each of the teachers articulated a desire to make changes in their assessment practices but felt constrained by time, lack of opportunity to talk with colleagues, and the expectation to present a prescribed number of topics.

The National Council of Teachers of Mathematics (NCTM) recently released two documents which propose to dramatically change the content, instruction, and assessment of school mathematics and the preparation of teachers of mathematics. The documents are the Curriculum and Evaluation Standards for School Mathematics ( NCTM, 1989) and the Professional Standards for Teaching Mathematics (NCTM, 1991). The documents were developed through an unprecedented level of collaboration between mathematicians, mathematics teachers, mathematics teacher educators, and representatives from business, industry, and other academic disciplines (Crosswhite, Dossey, & Frye, 1989). The recommendations made in the Standards Documents have resulted from the recognition that our understanding of how students learn mathematics has departed from current practices in mathematics education. Conventional forms of instruction and assessment do not address current emphases on understanding and problem-solving.

Four teachers who were known to have begun implementation of the instructional practices suggested by the NCTM Standards Documents were studied so their instructional and assessment practices could be profiled. Interviews, observations, and collections of teacher–used materials provided information concerning the two types of practices. They are referred to in this paper as Mary, Andy, Tom, and Helen.

The study was performed in the Puget Sound area of Washington state. School district mathematics coordinators and the state mathematics supervisor compiled a list of nominees for this study. The coordinators listed and rank-ordered the names of ten teachers according to the coordinators' knowledge of the teachers' level of implementation of the Standards Documents in their teaching practices. The coordinators used sections selected by the investigator from the Standards Documents (listed below) to guide their nominations and rank-ordering. The list was used to contact nominees to see if they were interested in being a part of the study. Only five calls were needed to secure the four participants.

Teachers' instructional practices were profiled according to the aspects that are to receive "Increased Attention"and "Decreased Attention", as summarized in the Curriculum and Evaluation

Standards (NCTM, 1989, p. 129). The major changes in patterns of instruction proposed for grades 9–12 can be summarized with:

| INCREASED ATTENTION to— | DECREASED ATTENTION to— |
|---|---|
| •The active involvement of students in constructing and applying mathematical ideas | •Teacher and text as exclusive sources of knowledge |
| •Problem solving as a means as well as a goal of instruction | •Rote memorization of facts and procedures |
| •Effective questioning techniques that promote student interaction | •Extended periods of individual seatwork practicing routine tasks |
| •The use of a variety of instructional formats (small groups, individual explorations, peer instruction, whole-class discussions, project work) | •Instruction by teacher exposition |
| •The use of calculators and computers as tools for learning and doing mathematics | •Paper-and-pencil manipulative skill work |
| •Student communication of mathematical ideas orally and in writing | |
| •The establishment and application of the interrelatedness of mathematical topics | |
| •The systematic maintenance of student learnings and embedding review in the context of new topics and problem situations | |
| •The assessment of learning as an integral part of instruction | •The relegation of testing to an adjunct role with the sole purpose of assigning grades |

Teachers' assessment practices were profiled according to the aspects that are to receive "Increased Attention"and "Decreased Attention", as summarized in the Curriculum and Evaluation Standards (NCTM, 1989, p. 191). The major changes in patterns of assessment that the document proposes can be summarized with:

| INCREASED ATTENTION to— | DECREASED ATTENTION to— |
|---|---|
| •Assessing what students know and how they think about mathematics | •Assessing what students do not know. |
| •Having assessment be an integral part of teaching (Note: this is the same as "The assessment of learning as an integral part of instruction" above.) | •Having assessment be simply counting correct answers on tests for the sole purpose of assigning grades |
| •Focusing on a broad range of mathematical tasks and taking a holistic view of mathematics | •Focusing on a large number of specific and isolated skills organized by a content-behavior matrix |
| •Developing problem situations that require the applications of a number of mathematical ideas | •Using exercises or word problems that require only one or two skills |
| •Using multiple assessment techniques, including written, oral, and demonstration formats | •Using only written tests |
| •Using calculators, computers, and manipulatives in assessment | •Excluding calculators, computers, and manipulatives from the assessment process |

The teachers who participated in this study shared many characteristics and differed on many others. Their instructional styles included both conventional and constructivist techniques, many using models which are proposed in the Standards Documents. The participants' assessment methods were consistent their instructional practices.

The participants used many similar classroom management and instructional strategies. Administrative tasks, such as providing a way for students to know past, present, and future assignments were "automated" so that students could perform the tasks themselves allowing more of their teachers' time to be spent on instruction. All the participants grouped their students to facilitate student-student interactions. The participants actively searched for ways to involve all students during each class period and provided ways for students to visualize concepts. Each of the participants also gathered information during class sessions to help guide their presentations, gave whole-class lectures at times, received assignments in "bundles" rather than daily, and had a specified procedure students had to follow to retake tests.

Each of the participants was familiar with the Standards Documents and actively pursued implementation of the spirit of the documents. Every one of the participant was teaching according to some part of the Standards Documents because of experiences that were unrelated to the documents themselves. Each of the participants could identify an event in their lives that lead to their current practices, which are representative of many parts of the Standards Documents. In every case, the participants began a conscious break from conventional instruction before the writing of the Standards Documents.

Mary

Mary's teaching practices were the most conventional of the four participants. She spent nearly all of every period discussing and explaining while her students watched, listened, participated, or were inattentive. Her assessments were consistent with her instruction: checking for correctness of response and procedures.

Mary began her teaching career in the early 1970's. She was able to attend workshops offered through a National Science Foundation grant that trained teachers on the use of mathematics manipulatives. Mary became proficient enough with the manipulatives that she taught a mathematics manipulatives class at the university in her town. During the class sessions I observed, Mary used manipulatives and visuals in her explanations but gave students few opportunities to do the actual manipulation. She had students demonstrate with manipulatives, measure with protractors, and cut out figures, but only to validate rules that she had given them. Manipulatives and calculators were allowed during tests, but since manipulatives were used only in demonstrations rather than knowledge construction and answers usually involved skill replication with small whole numbers, students rarely opted for the use of either.

Mary's instructional style involved mostly "show and tell" without giving students many opportunities to construct their understanding. Mary told them what they were to know and tested for that knowledge by having them replicate procedures. An example of this is when Mary chose

to assign a large number of exercises which drilled the same skill rather than giving questions about a limited number of situations which addressed a number of ideas about the same concept.

Mary's assessment practices checked mostly for correctness and amount completed. She checked whether students worked each assigned exercise and gave the papers a point value when they were collected with chapter tests. Seeing them at this time was too late for her to make any pedagogical changes, however her class discussions showed little variation even when students' responses indicated a need for change. Mary drew a diagram which contained a flaw, to which students alerted her, but to which Mary judged it unimportant enough to fix. Mary's assessments were consistent with her instruction because they both emphasize correctness of procedures and answers. Mary demonstrated examples and quoted rules such as "You can't arbitrarily move it over. Do you see why?" when she helped students with quiz corrections. The students got little help in understanding *why* the expression could not be moved over to the other side of the equation, just another example of mathematics as a discipline of memorizing and applying rules.

Ball's (1988) dissertation on prospective teachers found much of the same type of reliance on procedures with preservice teachers as Mary showed. The "image" of teaching which Mary must still carry from her early experiences as mathematics student are demonstrated in her teaching. Although Mary had substantial experience as a mathematics teacher and was expert enough to be recommended for this study, she was little more than a conventional teacher who placed her students in groups and demonstrated mathematical concepts with manipulatives.

Mary reported that she has never been completely satisfied with her teaching practices because there will "probably always be a better way". Her plans for change focus on finding projects and problems to change her assessment practices. She felt there is "too much testing for skills and facts and not enough assessing for thinking and extending". Mary felt that she knows what her students know and don't know, but has encountered "surprises". She said she wanted to find ways to decrease the probability of being surprised in the future. Mary planned to search for a course or workshop which addressed open-ended and project questions but had not found any offerings as of this writing. It is interesting to note Mary's intent was to use an assessment

alternative to help her progress instructionally. Given some ideas and materials, Mary would begin using project questions immediately in some of her classes. Mary voiced a need for external support to advance in her desired direction, but found her next steps difficult because of the lack of offerings and the pressure that she felt to teach at a prescribed pace.

Mary's implementation of the Standards Documents

Mary was at a partial level of implementation of each of the "increased attention" portions of the Standards Documents. To gain active involvement of her students in constructing and applying mathematical ideas, Mary's students were involved in exercises which enhanced their understanding of mathematical concepts; however, Mary identified key relationships within the concept and their qualities. Control of what students learned was maintained by Mary, who actively demonstrated and explained the concept to be learned before or during the students' investigation. Mary used manipulatives in her demonstrations, but students remained passive recipients of the relationships which she demonstrated for them.

Problems appeared in Mary's instruction, but lacked connection with the real world. Mary used contrived situations and exercises rather than having students refine questions and collect their own data. Exercises dominated her instruction for the sake of practicing given rules rather than problems being used to develop understanding.

Mary's questioning allowed for interaction among the students, but the resulting discourse required direction from the Mary to maintain its intended outcome. Students learned from their listening and talking, but reliance on the her was still present. Mary frequently used "are there any questions", to gauge student understanding and probed with "Is this OK?". Mary used very short wait-time with her questions. Her questions were of a leading nature with few responses requiring higher-level thinking.

With regards to instructional variety, Mary used "class problems", small group work, routine exercises, puzzles, and homework quizzes, but students did not frequently work on activities which required collaboration. Mary's students occasionally measured figures to determine a

relationship, but she pointed out what they should see. Mary made almost exclusive use of the conventional lecture/discussion format for instruction.

On the integration of technology into instruction, calculators and computers were allowed in Mary's classroom, but they were used almost exclusively for a fast way to find numerical answers. Mary even told students she could think of no reason to use calculators. The exercises Mary assigned provided no compelling reason to use calculators because they were skill-oriented rather than concept building and ordinarily had relatively small, whole-number solutions. Students commonly did not build understanding with manipulatives nor calculators, so using them during assessments was contra-logical to both Mary and her students.

Mary facilitated student communication by grouping them in threes to give them the opportunity for discussing their work Mary treated mathematics as a structured system with the bulk of the understanding told by her rather than created by the students. Students defended their answers orally and performed exercises on the chalkboard, but Mary remained the provider of relationships, rules, and concepts.

To establish the interrelatedness of mathematical topics, Mary assigned exercises which created connections between topics, but they were contrived rather than being found in the "real world". Mary used exercises for her students to practice skills instead of problem situations for concept building. Other uses for mathematical ideas were presented, but the connections were formed by Mary rather than her students. The reasons behind the connections were not apparent within the lessons.

Mary handled review by assigning exercises which reviewed concepts which were not currently under study. The exercises were from previous text pages or from various other mathematical topics but did not involve problem situations.

Mary's assessment methods involved collecting information through questioning, quizzes, tests, and assignments but they were not used to alter the her instruction substantially. Assessments facilitated a clearer picture of the students' capabilities, but had little significance beyond use for grading. Mary's interest in student responses was primarily for checking

correctness of answers rather than for understanding. Answers and how they were derived were reviewed by Mary, but the information was mainly used for correction of students' faulty algorithms and as a score by which grades were determined. The variety of sources which Mary used were limited but still gave some picture of student understanding. Students answered questions in class, demonstrated exercises on the chalkboard, worked assignments that were collected as a bundle, and completed tests and quizzes. There was no apparent systematic organization to the information gathered.

Andy

Andy's teaching practices were mostly conventional in the way he presented material in class, but closer to the recommendations of the Standards Documents in the way he allowed students to construct their understanding. He spent most of every period discussing and explaining, but it was always in relation to the investigations his students had undertaken the previous day. In this way, the discussions were used as a summary rather than the primary method of information transferral. His assessments were consistent with his instruction: problems related to the students' experiences.

Andy reported he had been teaching in a highly conventional manner for most of his career. Recently he had the option of adopting an innovative curriculum package in his classroom. The Sunburst Geometry series allowed Andy to use a problem-centered approach and to allow students to work at the construction of their own understanding. Andy's students learned concepts by completing activities from their text. Each major topic of the students' text contained sections which were organized around experiments, reading, projects, and analysis. Andy continued to lecture and question in a conventional way but interpreted his role as facilitator of his students' investigations. He enjoyed the approach and felt that it worked well for his students, but wondered whether less able students could learn this way. Andy reserved whole-class discussions to check for students' understanding of the concepts. The class sessions operated conventionally as Andy asked for answers to the investigation questions.

Andy's questioning prompted changes in his discussions, unlike Mary who just checked for students' ability to replicate her examples and rules. He was able to detect a student's misunderstanding of "vertical angle" by her response to a question. Andy continued to question her when she parroted the suggestion of another student, forcing her to explain what she meant by her previous comment. He asked some questions which required thoughtful reflection; some that required measuring, comparing, and analysis; and, some that only needed simple responses.

Andy used computers which operated specifically selected software to build student understanding. The students' text was keyed to one set of software (Geometric Supposer) which the students used as the investigations required. Andy also began using another set of software (Geometer's Sketchpad) for which he began to write questions. Although it was the Sunburst curriculum that helped Andy make the move to teaching more like the suggestions in the Standards Documents, he indicated by his remarks that he was preparing to continue his development with the same model using the newer software.

Andy assessed his students in a way consistent with how he taught. He gave problems which required investigation and synthesis on tests and quizzes, which he copied from text support materials. Andy also wrote questions and checked for the correct performance of procedures. He did not read all of the papers which students submitted, rather he "kept them honest" with "homework quizzes" and graded by the number of problems students completed on time.

Andy was a proficient computer user and planned to use technology to help him with further pedagogical advances. Andy articulated an interest in having his students spend more time on the school's computers to investigate and conjecture. Andy's background as a mathematics student was very conventional, however he has found enough value in computer assisted interactive learning to make it a priority in his professional development. I feel that as Andy continues to teach in this environment, he will begin writing the kinds of questions which lead to student investigations and subsequently implement the Standards Documents more completely. Andy's case is a good example of how an excellent curriculum package can help a willing and resourceful teacher move more towards the ideals suggested in the Standards Documents.

Andy's implementation of the Standards Documents

Andy implemented many of the "increased emphasis" portions at a complete level. Andy used problem situations which required more than one step in the assignments that he gave. Many problems were from real-world situations which required the application of more topics of mathematics than the students were presently studying. Andy's students were continually exploring mathematical relationships which were driven by questions and summarized by Andy.

Andy integrated technology into his instruction by having four-function calculators readily available to students, who used them while working nearly all activities. Computer activities were an essential part of the curriculum Andy used.

Andy established the interrelatedness of mathematical topics by facilitating the connections within mathematics and those between mathematics and other disciplines. Questions which linked algebra and geometry, and tiling investigations established a relationship between mathematical topics. Numerous opportunities were given students to develop different representations for mathematical concepts. The relationships between the representations that the students created were facilitated.

Andy maintained student learning and embedded review by assigning problem situations, developing new mathematical ideas, and providing an opportunity to integrate previously learned mathematical relationships. Andy assigned problem situations which stimulated students' discussion on mathematics, involved multiple mathematical topics, and facilitated connections within and outside of mathematics. The problems had real-world representations, had multiple means by which they could be solved, and allowed for discussion and extension.

Andy implemented the remaining "increased emphasis" portions at a partial level. To gain active involvement in constructing and applying mathematical ideas, Andy's students derived mathematical concepts through the use of strategies such as reading, experiments, analyses, and projects. Andy acted as a facilitator of the activities for the students while the work was progressing, but was not the provider of the concept that the students were learning. Andy

discussed the connections between ideas and summarized the student's work in a conventional whole-class approach, providing the students with the facts of the key relationships.

Andy's questioning techniques placed him at the center of all discussions as he checked for their understanding and students checked their answers. Students learned from their listening and talking, but reliance on Andy was still present. Questions tended to be of a leading nature with few responses requiring thinking beyond what students had already written on their papers.

The instructional formats Andy employed were varied, but few. Andy used whole-class discussions for summarizing concepts and checking students' answers and facilitated students' understanding while they worked through their activities. He also took them to either of two computer labs for concept development using specialized software. Students worked on activities that encouraged collaboration.

Regarding student communication of mathematical ideas, Andy structured activities so students relied on the discussions in their groups to aid concept development. Whole-class discussions were orienting rather than providing a means for deeper conceptual understanding. Mathematics was treated as a structured system with Andy summarizing the rules to be learned.

The assessment techniques Andy used employed multiple methods, but were not used to alter Andy's instruction substantially. Assessments revealed a clearer picture of the students' capabilities, but had little significance beyond use for grading. Andy's interest in student responses was primarily for checking procedures rather than understanding even though he checked for more than correctness of answers. Answers and how they were derived were reviewed by the Andy, but the information was mainly used for reiteration of previously developed rules and as a score by which grades were determined. The variety of sources Andy used were limited but still gave some picture of student understanding. There was no apparent systematic organization to the information gathered.

Tom

Tom's teaching practices were conventional in the way he organized class discussions. Tom addressed many of the recommendations in the Standards Documents by attempting to develop projects and kinesthetic experiences which would enhance students' understanding. Tom used whole-class discussions as the primary method of information transferral, although he said "I know I am still talking too much." His assessments were consistent with his instruction: conventional exercises for which students demonstrated knowledge of procedures and questions which addressed student understanding of concepts.

Tom grouped his students throughout his teaching career, but said he always retained control of the discussions. In this respect, Tom made a decision before the release of the Standards Documents to teach differently than he had learned. Tom decided to make further changes in his teaching practices after taking a mathematics problem-solving class at a local university. He was challenged mathematically by problems and had the opportunity to reflect on that experience. He was immersed in situations which were designed to apply the Standards Documents and began to wonder whether students learned anything in conventional settings. A subsequent class in learning theory increased Tom's doubt about the effectiveness of his past teaching methods. Tom's course work began the summer before this study, making his *recognition* of the paradigm of instruction promoted by the Standards Documents the most recent of the participants.

Tom's instructional practices allowed his students to formulate some concepts themselves and to be checked on their understanding in the forum of the classroom. He had students draw graphs on their own, then use a graphing template to help with graph translations (sliding). During their work, Tom's students formulated their own rules for how to perform translations, which were challenged during class discussions and questioning. Tom's use of this method paralleled Andy's choice of curriculum, which provided problems that promoted investigation. The two teachers chose to use class discussions to check for students' understanding of the concepts and to summarize the situations. The two teachers differed with respect to the origin of the situations: Andy's was from his curriculum and Tom's was from his own pedagogical decision. The two

further differed on how the situations were summarized: Andy gave the formal rules as the question about the relationship arose and Tom had students discuss their understanding first, then confirmed the rule. The latter difference, although seeming to put Andy's method in a negative light, may be due to the directed nature of the questions Andy used for investigation and the fact that his students had opportunities previous to the class discussion to talk over their understanding.

Tom adapted his instruction to how he perceived students' understanding, based upon students' responses during class discussions. When he realized students did not understand his drawing of three dimensions, Tom abandoned his lesson plan and asked students to create a model. He carried his perception over to his next class by having students stand in specific places of the room to represent three dimensions before assigning the project to them.

Tom's assessment methods were very much like his teaching methods. The questions he asked on tests and quizzes contained questions from the text materials which asked for replication of procedures, and questions which tested for student understanding. Sometimes Tom's students questioned his use of such problems, claiming he had never taught them "how to do it." Tom sympathized with their frustration and was frustrated himself about his students' desire to only be held accountable for procedures: "they just want to know how to get the answer, not what it means." Tom articulated a desire to alter his evaluation procedures but found no good models from which to adapt. Tom's performance as a teacher, just as with Mary and Andy, is effected by his *image* of teaching, built by his experiences as a learner. His image of teaching was challenged recently through his own experiences as a student, prompting a revision of his methods.

Tom asked some questions which required thoughtful reflection, some that were answered simplistically, and others that he was not sure of how they were going to solve. Tom still dominated the conversation in his classroom, but made a conscious effort to promote more student discussion and to invent problems for his students. Tom expressed an overwhelming desire to make advances in his implementation of the Standards Documents and discussed plans to look for courses, discussions, and trial-and-error in his own teaching to help him. Tom experienced a

cognitive dissonance as a student which forced him to evaluate his instructional and assessment methods. He is striving for change but did "not know what the product would look like."

Tom's implementation of the Standards Documents

Tom implemented many of the "increased emphasis" portions of the Standards Documents at the complete level. He demonstrated the use of a variety of instructional approaches by using small-group and large-group formats for instruction. Project questions were occasionally given which prompted student discussions in their groups. Tom relied most heavily on a conventional lecture/discussion format for instruction.

Tom established the interrelatedness of mathematical topics by actively facilitating connections within mathematics and those between mathematics and other disciplines. Numerous opportunities were given students to develop different representations for mathematical concepts and to check their own conceptual understanding. The relationships between the representations the students created were facilitated and discussed.

Tom integrated assessment and instruction by using multiple assessment methods such as oral questioning and checking students' daily work. Assessments were frequently used to alter Tom's instruction as he adapted his teaching to the students level of understanding. Assessments achieved a clearer picture of the students' capabilities.

Tom implemented the remaining "increased emphasis" portions at a partial level. To involve his students in active construction and application of mathematical ideas, Tom assigned his students projects which enhanced their understanding of mathematical concepts, however, he identified the key relationships within the concepts. Tom retained control of what students learned as he actively demonstrated and explained the concept to be learned before or during the students' investigations.

To address problem-solving as a goal of instruction, problems appeared, but many lacked connection with the real world. Tom assigned exercises from the text that contained contrived situations rather than having students refine the question and collect their own data. Exercises

dominated the curriculum rather than problems. Tom did attempt to invent problems which were not routine and required higher-level thinking by the students.

Tom's questioning techniques involved asking key questions then letting the class interaction work at the solution as the students conjectured, judged the validity of arguments, and analyzed the appropriateness of the answer. Tom used appropriate wait-time to encourage thoughtful responses. Tom's questioning strategies facilitated interaction among the students, but the resulting discourse required his direction to maintain its intended outcome. Students learned from their listening and talking, but reliance on Tom was still present. Questions tended to be of a leading nature with only a few responses requiring higher-level thinking.

The use of calculators and computers was present in the classroom, but they were used almost exclusively for a way to find numerical answers. Tom also used the "Easy Grapher Template" to substitute for graphics calculators in concept building.

Tom provided for the communication of mathematical ideas by allowing students opportunities to discuss concepts and feelings, but the discussions were orienting rather than providing a means for deeper conceptual understanding. Rules were discussed and challenged, with Tom retaining control of the discussion pattern. Mathematics was treated as a structured system, but the bulk of the understanding was not created by students. Review was accomplished by assigning exercises from previously used parts of the text and by giving questions that wove together topics from geometry and algebra.

Tom assessed students' mathematical knowledge primarily for checking procedures rather than understanding even though he frequently checked for more than correctness of answers. Answers and how they were derived were reviewed by Tom, but the information was mainly used for correction of rule systems and as a score by which grades were determined. Problem situations occurred infrequently and connected a very limited number of mathematical ideas. The problems were commonly an algorithmic replication of recently presented material. Some problems had been formulated such that Tom was uncertain how students would answer them. The variety of assessment sources Tom used were limited but still gave some picture of student understanding.

He questioned while lecturing, asked for oral "proofs", encouraged pictorial representations of the students' ideas, and asked for their candid feelings. There was no apparent systematic organization to the bulk of information Tom gathered

Helen

Helen had been teaching for the least amount of time of all of the participants, eight years compared to at least twenty years for each of the others. In spite of her relative inexperience, she was by far the most advanced in completeness of implementation of the Standards Documents. Helen's instructional practices allowed her students to construct most concepts themselves and to be checked on their understanding in the classroom forum. Helen adapted her instruction to how she perceived students' understanding based upon students' responses during class discussions, quiz answers, and self reports. She asked many questions which required thoughtful reflection, some which were answered simplistically, and others which required investigation or data gathering to solve. Helen's assessments comprised gathering multiple forms of information and involvement of students in the assessment process.

Helen's primary mode of "information transfer" was to have students work collaboratively on problems while she monitored their progress. Unlike the other participants, Helen allowed students to do most of the talking while she directed students' learning with questions. Helen held whole-class discussion only to summarize students' findings and address questions related to students' investigations. Helen's instructional style was an application of problem solving, communication, reasoning, and mathematical connections. Helen also integrated assessment into being part of instruction. Helen's instructional methods were exemplary of the recommendations found in the Standards Documents.

Helen's assessment methods provided her with information which was both useful and frustrating to her. She felt her students came to her class with limited knowledge of algebra and gained understanding while there, but resisted her less direct methods. As she wrote in her journal "Sometimes I wonder whether they learned anything before my class" but students wrote "You

aren't teaching us" when she asked about how their experience was going. The challenge for students to be more responsible for their understanding was expressed as a desire to provide more direction, to perform more examples – to do "more teaching". Helen made no substantial change in her methods because of the student reports, but she did respond with sensitivity to their concerns. She announced when she performed examples and gave students opportunities to reflect on the teaching act. Helen learned from journal entries that when students had an opportunity to teach the class they gained new respect for the teacher's job.

Helen made students part of the assessment process by having them "grade" themselves before each quiz. Helen used the "skill matrix" to facilitate student involvement in the assessment process, to provide another learning situation, and to provide a forum for reflection. Students mostly agreed with her evaluation of their capabilities, which helped identify areas of weakness and notable accomplishments.

The questions Helen asked modeled currently discussed assessment methods. The levels of questions which Helen posed in her tests were much like the SOLO taxonomy proposed by Biggs and Collis (1989) where questions about a situation are hierarchically organized. This organization reveals the levels of students' understanding by which parts they answered correctly and the type of responses they gave.

Helen attributed her teaching practices to getting a really solid start as an undergraduate. Much of Helen's work involved the use of manipulatives and small-group instruction strategies that she learned from Project EQUALS and Marilyn Burns workshops. She was able to synthesize her experiences with a course on conceptual understanding. Helen's experiences as a learner contributed to her image of teaching as one of a facilitator of understanding rather than an expositor of knowledge.

Helen articulated a desire to make changes in her assessment techniques by finding ways to get her students more involved in their own assessment. She felt that there would be value in having students check themselves and others for correctness. She wanted to find some way to release

herself from that responsibility since she already knew the math and the students were the ones who needed more work on it.

Helen's implementation of the Standards Documents

Helen implemented each of the "increased emphasis" portions of the Standards Documents at a complete level, but continued to search for ways to do more. She said she saw so many ways to improve what she did, but had limited time in which to implement those changes. She relyed on students actively working to construct their understanding, but they had the power to thwart her efforts by not completing their responsibilities or by being untruthful on self assessments. Given her situation, I see no "improvements" which she could make.

Helen gained the active involvement of students in construction and application of mathematical ideas by having them derive mathematical concepts through the use of strategies such as problem situations and projects. Helen acted as a facilitator of the students' activities while the work progressed, but was not the provider of the concept the students were to learn. Helen discussed the connections between ideas and summarized the concepts in what appeared to be a conventional whole-class approach. Helen's students formulated the basis of the concepts to be learned instead of being told the relationships by the her.

Helen used problem-solving as a goal of instruction by assigning real-world problems which required more than one step and were occasionally ambiguously formulated. The problems were from real-world situations which required the application of more topics of mathematics than the students were presently studying. Helen widely used problem situations which featured the application of students' mathematical understanding to novel situations.

Helen's questioning techniques allowed students to be the ones who gave and verified the answers to questions they may even have asked themselves. Helen asked key questions then let the class interaction provide the solution as students conjectured, judged the validity of arguments, and analyzed the appropriateness of their answer. Helen used appropriate wait-time to encourage thoughtful responses and always asked for students' feelings of reasonableness of responses.

Helen demonstrated instructional variety by creating a learning environment which was a place where more than one method of instruction was used and expected. As the content varied, so did the methods she used in its presentation and exploration. Helen masterfully used small-group interactions to facilitate the development of conceptual understanding.

The use of graphing calculators was integrated into the activities of Helen's mathematics classroom. The calculators were used for both a fast way to get a numerical answer and a platform for mathematical investigation. Using the technology as a medium for exploration, students were able to hypothesize and verify relationships which were posed in problem situations. All mathematical activities posed by Helen had an element of technology to them, including student assessment.

Helen provided numerous ways for students to communicate mathematical ideas and to express their understanding. Their discussions and writings used appropriate vocabulary, grammar, and symbols of the mathematical ideas they were trying to express. There was ample accommodation for reflection and clarification of mathematical ideas. Articulation of mathematical relationships which had been derived from investigations was evident.

Helen established the interrelatedness of mathematical topics by actively facilitating connections within mathematics and those between mathematics and other disciplines. Numerous opportunities were given students to develop different representations for mathematical concepts. The relationships between the representations her students created were facilitated.

Helen systematically embedded review by having her students work on the same general ideas but with increasingly deeper and broader scope. The problems she assigned developed new mathematical ideas and also provided an opportunity to integrate previously learned mathematical relationships.

Helen integrated assessment with instruction by using multiple forms of assessment to achieve an authentic picture of student understanding. Unconventional forms of assessment such as interviews, papers, project questions, and open-ended questions were among her methods. Data from assessments were used for diagnosis, instructional feedback, student comparisons, and

grading. Assessment were in alignment with instructional practices which emphasized problem solving, reasoning, and communication. Helen also made provisions for students to play an active part in their assessment. Assessments were used to produce a detailed picture of student learning and were used as a basis of for improving the quality of instruction. Students' activities, discussions, homework papers, notebooks, essays, quizzes, test papers, and oral reports were used to determine students' level of understanding so that consistency in a variety of situations could be determined. Students were continually pressed to explain their reasoning and demonstrate their level of understanding. Assessment information was gathered from all of the activities that students encountered in Helen's class, demonstrating the variety of assessment techniques Helen used. Assessments did not involve each student all of the time. Data on students' understanding was gained both formally and informally by the use of interviews, tests, quizzes, project questions, homework assignments, observations of interactions with other students, and oral reports. The information was collected, recorded, and handed back if appropriate.

Helen provided problem situations which stimulated students' discussion on mathematics, involved multiple mathematical topics, and facilitated connections within and outside of mathematics. The problems she gave students came from real-world settings (such as the newspaper or television), had multiple means by which they could be solved, and allowed for discussion and extension.

## Summary

Each of the participants seems to have specialized in an area of emphasis suggested in the Standards Documents. Mary was an expert in using manipulatives in demonstrations, Andy was working toward the integration of computers into his instructional practices, Tom was working on questioning techniques and projects, and Helen specialized in student assessment, although she was advanced in all areas. Each of the participants was helped along the way to implementing the Standards Documents by some focal events, had support for change, and continued to work for change.

An unexpected finding was the use of a conventional lecture/discussion approach by all teachers. Observing a teacher leading a whole-class discussion was not sufficient to judge her level of implementation of the Standards Documents. The teachers who had students construct understanding through activities used these times to summarize and extend the concepts which were explored by the students. More conventional teachers used these times to inform students of rules and relationships before the students attempted problems or exercises. The number of students who participated in the discussions was always limited, reinforcing the suggestion in the Standards Documents to use a variety of instructional approaches.

Another unexpected finding was teachers' instructional practices and assessment practices were aligned. I expected to see teachers teaching by the Standards Documents and assessing in conventional ways. Mary taught in the most conventional way, so she gathered little information about her students' understanding. Her primary interest was students' correctness as she checked assignments, quizzes, and tests. This may have been because she felt her teaching was driven by factors external to the students. Andy asked questions which checked for understanding and altered his teaching with the information he gathered. His students worked on experiments which were part of the adopted curriculum. He probed for understanding during discussions, but remained the center of those discussions. Tom went a step further: he altered his instruction to the extent that he completely abandoned his lesson plans for a few days based upon what he realized students understood poorly. He made changes in his instruction based on information gathered from students. Helen developed lessons which were constructivist in nature and therefore relied on multiple forms of information about their understanding. She checked students' processes in solving real-world problems and involved them in a cyclic process of assessment.

As the Standards Documents suggest, instruction and assessment *are* inextricably linked. Teachers cannot develop into interactive, conceptually-oriented, constructivists without having assessment tools which support them. Teachers may progress instructionally only as far as their assessment techniques allow. Mary, Andy, Tom, and Helen struggled to advance their instructional techniques, which relied on a concomitant advancement in assessment techniques. A

deeper understanding of what students understood allowed instruction to be interactive and student-oriented rather than teacher-directed. Mary merely checked answers, so she was unconcerned when students gave the right answer for the wrong reason. Andy "lectured" frequently, but they were in relation to what the students concluded in their investigations. Tom implemented projects to clarify concepts when students' responses revealed they had poor understanding. Helen included assessment in all phases of her problem-oriented instruction so she and her students were aware of their understanding.

Assessment methods which reveal student understanding must become an integral part of teachers' professional preparation. Assessment is the area in which each of the participants in this study felt the weakest and in which they planned their next change to occur. Planning for instructional change necessarily includes assessment revisions.

## Implications for implementation of the Standards Documents

Enough has been said in the literature for us to understand that change must be supported, systemic, and gradual. There will always be a few people that defy change and a few that relish it.

For people to *want* to change, there must be some reason. Their present way of doing things must be shown to have weaknesses. Tom's experience with the problem-solving class and the learning theory class forced him to conclude what he was doing instructionally required modification. He was open to alternatives once he saw the weakness of his practices and had experiences in a new paradigm of instruction. It is important to note that Tom was naturally reflective and willing to change when reason dictated it. Not everyone will accept change if their present paradigm is shaken, particularly if they are not reflective individuals.

Implementation of the Standards Documents will proceed differently for each teacher. Not only will teachers choose different portions of the documents to implement first, but they will also attempt their implementation at different times. Implementation will appear spotty instead of uniform as teachers learn from their experiences. Tom grouped his students but controlled most of the conversation. He attempted implementation of the Communication standard but was not

consistent with the use of groups for collaborative problem solving. Tom wanted to increase students' involvement and responsibilities but needed more time and support in accomplishing the shift as he experimented with other instructional techniques. His practices and intents suggest supporting implementation by providing a variety of experiences, expecting a variety of outcomes, and establishing a cycle of assessment and feedback.

There must be many levels of support for change. Teachers need time to process what they are learning and to adapt it to their situations. Teachers have busy lives: the curriculum is crowded, classrooms are being populated by increasingly diverse students, and regular teaching duties take a lot of time. Mary would have liked to make more changes in her teaching but felt "too busy to be creative." Tom wanted help in his assessment practices but found few alternatives in use by his colleagues and instructors. Teachers need time away from school and the responsibilities that it imposes for change to develop. Limiting ourselves to evenings, weekends, and summers for the kind of work we want teachers to do can only make the process more difficult for them. They need extended periods of time to work on mathematics in problem situations, talk with their colleagues, observe other teachers at work, and try out their ideas with ample opportunities for reflection, feedback, and revision. One reasonable way to accomplish this would be to permanently shorten every teacher's workday to provide the time necessary for professional growth.

Finally, for teachers to really make strides, they must have a firm grounding in school mathematics. To teach the way the Standards Documents suggest, teachers must possess deep conceptual knowledge themselves. We must make sure that teachers who are being prepared for change learn mathematics through problem situations that force them to communicate, reason, and make connections. The mathematics instruction must be context-rich in both real-world applications and school mathematics situations. Helen is an expert in mathematics, which makes it easier for her to understand her students' conceptual difficulties and to design situations to help them overcome their difficulties. Her combination of subject matter knowledge, humor, insight,

and grounding in unconventional instructional and assessment techniques have helped her to progress to an exemplary level.

The model proposed in the Standards Documents is lofty indeed, but Helen has proved it attainable. Preservice teachers who learn mathematics content and mathematics teaching methods through experiences which are consistent with the Standards Documents have a good likelihood of teaching much like Helen. Experienced teachers would benefit from the same experiences but may need more support than novice teachers to modify their present, and often successful, practices. Tom attempted change but found it frustrating for him and his students. Andy modified his practices with the new curriculum but was making only small steps outside the curricular support materials. Mary *said* she wanted to make changes but was comfortable enough with her present practices to repeat the exact same lecture, and occasionally the same errors, to subsequent classes.

The Standards Documents can be implemented at least partially by teachers who see the benefit of having students work to create their own understanding. Helen's preservice experiences facilitated her transition to high levels of implementation, and Tom's renewal after teaching twenty years provides exciting possibilities for teacher educators. Helen's practices and Tom's potential show us what can happen and how to facilitate implementation of the Standards Documents.

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